A Web based FMECA Interface Linked to an Expert System for Oil Analysis

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Abstract: A World Wide Web (WWW) interface to a FMECA (Failure Mode Effects and Criticality Analysis) building tool and database is described in this paper. The WWW FMECA has been linked to an oil analysis expert system. The interface is based on an Oracle 7 distributed database tightly integrated with Web server functions. A second laboratory Oracle distributed database contains historical oil analysis data. A rule-based expert system accesses both databases and matches pertinent failure mode and detection method details from the FMECA database with current and statistical trend data from the laboratory database. The FMECA database contains both public and private data. Publicly accessible tables contain failure rates, failure mode distributions, causes, effects, detection methods, and severity classifications while private tables contain the failure mode analyses accessible only to the authenticated user. The general data tables provide cooperative and synergistic advantages to a diverse spectrum of users and industries. These advantages include consistent naming of parts and failure modes even where multiple languages are used. The FMECA database provides knowledge that is easily assimilated by an expert system.

Key Words: Condition monitoring, condition based maintenance, expert system, failure modes and effects criticality analysis, oil analysis, World Wide Web.

Introduction: FMECA, an acronym for 'Failure Mode Effects and Criticality Analysis', is a procedure for equipment reliability analysis developed by NASA and the aerospace industry and used extensively in the United States armed forces and in many large manufacturing companies. MIL-STD 1629A [1] provides a standard format for FMECA. FMECA has found use primarily in the design cycle of new products and systems because it offers a way to identify design deficiencies so that corrective modifications can be made. However, it has also been employed to a lessor extent within the maintenance planning

function [2]. Despite its many advantages FMECA is unknown among the majority of plant and maintenance engineers. Requiring training, organizational infrastructure, commitment and access to a reliable database of failure data, FMECA has not gained widespread recognition as a useful maintenance tool. This paper proposes a new approach to make FMECA more accessible to the general maintenance community.

There is a natural relationship between the principles of Condition Based Maintenance (CBM) and FMECA. FMECA includes among its procedures the identification of a *detection method* as well as the consequences or *effects* of each failure mode. Normally, in order for it to be practical, CBM must include an automated diagnostic capability. Commercial and in-house oil analysis laboratories may employ expert systems to evaluate current and trend data and to generate diagnostic reports [3]. The problem being addressed in this paper is the practical difficulty of improving the diagnostic precision of oil analysis expert systems. The solution envisioned comprises a World Wide Web based FMECA interface linked to an expert system and associated databases, schematically represented in Fig 1.

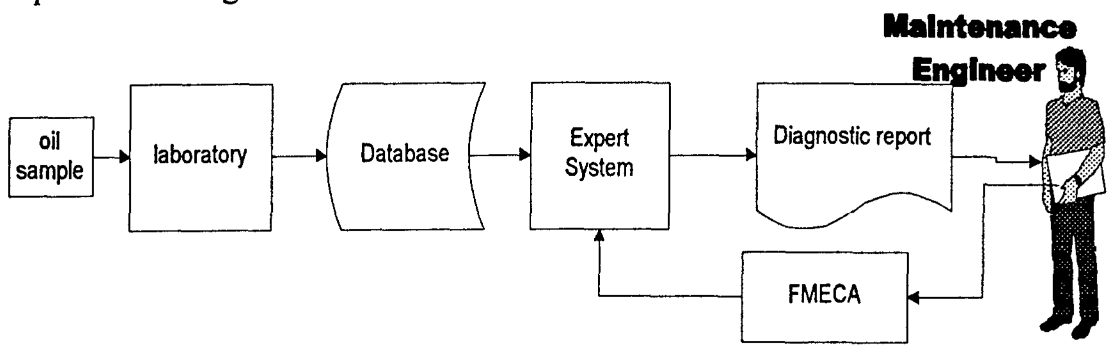

Fig. 1

Condition Based Maintenance in general, and oil analysis in particular, can be well served by the use of FMECA as their foundation. Using CBM without a preliminary analysis, one tends to collect large bodies of oil analysis data over a long period of time in the hope that trends will provide clues pointing to the failing equipment component as well as to the time remaining before the loss of that component's function. A FMECA, if performed early in the program, will guide the user in choosing an optimal set of condition monitoring techniques and relate the condition indicators to precise failure modes.

FMECA is a fundamental analysis technique that combines the analyst's intimate knowledge of each component's function, its failure modes, and the effects of each failure mode. One first collects detailed component information in a database. Useful reports are subsequently generated. Standard FMECA reports assist in the decision process regarding maintenance management policy on preventive and condition based maintenance. FMECA is the prerequisite to Reliability Centered Maintenance (RCM) [3]. At a minimum, the data compiled in the FMECA for each part are:

1. component
2. indenture level

3. failure rate, lamda
4. failure modes

For each failure mode for a component the data compiled are:

1. failure mode ratio, alpha (failure rate ratio lamda x alpha)
2. detection method
3. compensating provision
4. local effect
5. next higher level effect
6. end effect
7. severity class
8. failure effect probability, beta

A WWW FMECA program is a cost effective way to enhance an oil analysis expert system knowledge base. Ordinarily, *knowledge engineering*, that is, the acquisition of experience and its representation within a computer algorithm, is painstaking and expensive. It requires a high degree of motivation by operational personnel who must undergo interviews conducted by a *knowledge engineer*. These expenditures often have little or no immediate payback. Conversion of the gathered experience into useful knowledge in an expert system shell can be difficult where rule modifications perturb existing rules. The rule base requires periodic statistical validation against historical data.

FMECA can assist in relieving most of these problems. First, at the knowledge acquisition level, FMECA offers a tangible incentive for the user to expend time, money, and energy to provide the required domain experience. The incentive is the computer generation of useful FMECA reports, which help evaluate equipment reliability. A Web based FMECA interface allows the user to add her knowledge and experience to the rule base without without having to manipulate the algorithm within the expert system shell. The reliability reports facilitate maintenance management by demonstrating the calculated criticality of components thereby highlighting relative maintenance priorities. Since the laboratory expert system likewise publishes its reports on the Web, testing and validation are conveniently performed from within the same user interface.

The second set of problems is handled by the defined data structure exacted by the FMECA methodology. The user must, to use the FMECA software interface, be precise and systematic in specifying failure modes and effects for machinery and their components. The constrained format and strict definition of terms imposed by FMECA is, therefore, ideal for knowledge representation within an expert system.

The FMECA includes not only the failure modes and effects which occur in a system, but also the detection methods, severity classifications, and compensating provisions as illustrated by the Web input screen of **Fig. 2**.

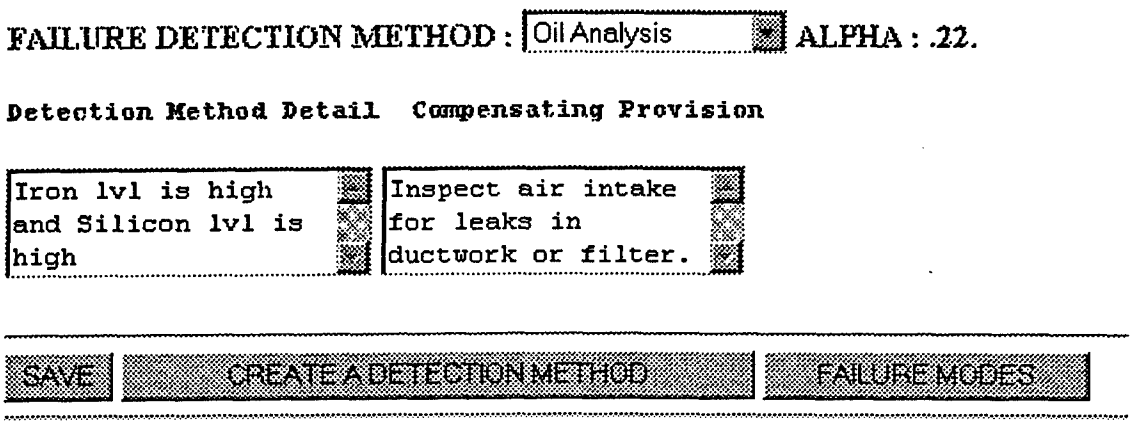

Fig. 2

The failure modes, effects, and detection methods enable the maintenance engineer to develop useful rules for inclusion into a CBM expert system. The *detection method* detail provides a triggering method for firing an expert system rule. The *compensating provision* provides the expert system recommendation. The *failure effect, severity classification,* and *failure effect probability* assign a priority within the diagnostic recommendation. The *failure mode* description and *part* description identify the likely modes of the failed component. Such vital detail, generally lacking in the reporting of many high volume automated oil analysis laboratories, is attainable through the use of an accessible Web FMECA tool as the front end to the expert system shell.

If we know, for example, that a failure mode for a system component, say a shaft, is 'misaligned' and it's *next higher level effect* is 'excessive noise' on the gearbox, an oil analysis *detection method* may state that the iron rate of increase is greater than .05 ppm/hr. The expert system rule could suggest the failure mode - namely shaft misalignment - is occurring and also suggest a confirming test for bearing noise or heat as described by the *next higher level effect.* Moreover, a statement of relative importance will have been included in the diagnostic report since the expert system will have accessed the *severity classification* and *failure effect probability* within the relevant FMECA database record.

The integration mechanism between the FMECA database and the expert system employs a database trigger to generate an appropriately formatted rule. This rule is appended to a file whenever a *detection method detail* record has been updated or inserted into the database table. The appended rule applies exclusively to the machine in question. Since the expert system shell requires that the rule be compiled, a timed UNIX command (cron) detects the modified rule file and executes the rule compiler. In this manner the expert

system becomes dynamic. That is, it is continuously 'improved' on-the-fly as FMECA data is updated by remote users. Otherwise stated, the FMECA interface empowers maintenance personnel to apply their specialized knowledge directly to the expert system rule base.

A number of benefits of the FMECA interface on the Web have been postulated:

1. Users gain a cost/benefit advantage because high-end hardware and software are justified where a single server serves multiple clients. (This would not be the case were these assets limited to single client use.)

2. The phrases describing machine types, components and failure modes are standardized. This standardization is effected through a feature of the software that encourages the user to search for an existing phrase that may spare her the task of creating a new one. By having everyone sing from the same sheet, rule maintenance and consistency are improved.

3. Given that FMECA is an already established and proven methodology, the proposed Web based interface to FMECA should expand the number of maintenance users who can benefit from it.

4. When an oil analysis report appears to be inadequate in predicting failure or establishing machine health, a FMECA is launched directly from the Web published report.

5. Since the general FMECA database tables are used and developed by multiple users from diverse industries, there is a synergy based on cooperative development and acceptance of FMECA phrases.

6. The software is always up-to-date. The Web FMECA user interface is an example of *thin client technology* that requires a minimal hardware configuration. Users need only a Web browser to access the software's full functionality. It is not necessary to maintain the software or the data on the client computer. Administration, backups, and upgrades are the responsibility of the server.

7. Failure rate and failure mode databases are maintained an updated for the user.

In a nutshell, a World Wide Web FMECA interface, provides the maintenance manager with the ability to understand the failure modes and their effects on the costs of maintaining her plant. This information appears in a variety of reports which highlight the failure modes and rank their criticality levels. These reports become the basis for important cost saving management decisions. At the same time, precise diagnostics are possible in CBM expert system-generated reports whenever a monitored parameter coincides with a *detection method detail* previously entered into the FMECA via the Web application.

The current version of the FMECA Web interface described in this paper consists of:

1. A rudimentary FMECA Web program accessed via a Web browser.

2. An Oracle database populated with suggested reliability failure mode data, FMD-97 [4], and failure rate data, NPRD-95 [5] accessed under license from the Reliability Analysis Center.

3. A help function linking to a FAQ (Frequently Asked Questions) hypertext document including FMECA examples.

5. An on-line tutorial which walks the novice through various sample FMECA examples.

6. Basic FMECA reports and user customizable reports.

Conclusions and future work: The Web FMECA interface is a promising new avenue towards the integration and unification of CBM techniques (other than oil analysis) into a common expert system. These include vibration analysis, thermography, and performance parameter monitoring which are considered additional detection methods in the FMECA database. The Web interface could be expanded to permit upload of data from these other condition monitoring sources.

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